

(19)



(11)

EP 2 532 867 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
25.03.2020 Bulletin 2020/13

(51) Int Cl.:
F02D 41/00 ^(2006.01) **F02D 41/14** ^(2006.01)
F02D 41/18 ^(2006.01) **F02D 21/08** ^(2006.01)

(21) Application number: **12170322.7**

(22) Date of filing: **31.05.2012**

(54) **AN EXHAUST GAS RECIRCULATION SYSTEM FOR AN INTERNAL COMBUSTION ENGINE**

ABGASRÜCKFÜHRUNGSSYSTEM FÜR EINE BRENNKRAFTMASCHINE

SYSTÈME DE RECIRCULATION DE GAZ D'ÉCHAPPEMENT POUR MOTEUR À COMBUSTION
INTERNE

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **06.06.2011 JP 2011125935**

(43) Date of publication of application:
12.12.2012 Bulletin 2012/50

(73) Proprietor: **Nissan Motor Co., Ltd.
Yokohama-shi, Kanagawa 221-0023 (JP)**

(72) Inventor: **Tsuyuki, Takeshi
Kanagawa, Kanagawa 243-0123 (JP)**

(74) Representative: **Osha Liang
2, rue de la Paix
75002 Paris (FR)**

(56) References cited:
**EP-A1- 2 447 516 US-A1- 2003 004 677
US-B2- 6 732 522**

EP 2 532 867 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

[0001] This disclosure generally relates to an exhaust gas recirculation (EGR) system for an internal combustion engine.

Description of the Related Art

[0002] In Patent Document 1 is disclosed a cooling system of EGR for an internal combustion engine in which an EGR control during a quick acceleration may be effectively performed. Specifically, an estimate or virtual EGR rate is calculated based on a pressure difference across an EGR valve. In addition, a target EGR rate is calculated from engine rotational speed. A difference between the virtual EGR rate and the target EGR rate is used to correct an EGR valve opening.

[0003] [Patent Document 1] Japanese Unexamined Publication of Application 2004-150343, which has a corresponding US patent, US Patent No. 6,868,329 to Ito et al. Further EGR control systems are disclosed in documents US2003004677A1, EP2447516A1 and US6732522B2.

SUMMARY OF THE CLAIMED SUBJECT MATTER

[0004] An object of the present invention concerns an exhaust gas recirculation device for an internal combustion engine having an intake air charging unit, the exhaust gas recirculation device comprising an intake air passage that intakes intake air for the internal combustion engine, an exhaust passage that carries away exhaust gas from the internal combustion engine, an exhaust gas recirculation passage connected to the intake air passage, an exhaust gas recirculation valve interposed within the exhaust gas recirculation passage, and an air charging unit comprising a compressor disposed in the intake air passage and a turbine disposed in the exhaust passage. The exhaust gas recirculation passage recirculates a part of the exhaust gas based on an openness of the exhaust gas recirculation valve to control an amount of exhaust recirculation introduced into the intake air passage. A first end of the exhaust gas recirculation passage is connected to the intake air passage upstream of the compressor of the intake air charging unit and a second end of the exhaust gas recirculation passage is connected to the exhaust passage downstream of the turbine of the intake air charging unit. The exhaust gas recirculation device further comprises an intake air detecting means for detecting an amount of the intake air upstream of the compressor, an intake air pressure estimating means for estimating an intake air pressure in a position in which the first end of the exhaust recirculation passage is connected based on the detected amount of the intake air,

a first exhaust gas pressure calculating means for calculating a first estimate of exhaust gas pressure in a position in which the second end of exhaust gas recirculation passage is connected based on the detected amount of the intake air and a second exhaust gas pressure calculating means for calculating a second estimate of exhaust gas pressure by applying a predetermined response-delay processing on the first estimate of exhaust gas pressure. The opening of the exhaust gas recirculation valve is adjusted based on a second pressure difference between the estimated intake air pressure and the second estimate of the exhaust gas pressure.

[0005] Embodiments of the exhaust gas recirculation device are defined in the dependent claims.

BRIEF DESCRIPTION OF DRAWINGS

[0006]

Fig. 1 shows a diagram schematically of an overall configuration of the EGR system for an internal combustion engine according to one or more embodiments of the present disclosure.

Fig. 2 shows a schematic diagram explaining an intake air pressure as well as exhaust gas pressure.

Fig. 3 shows a graph of an interrelationship between an amount of intake air and a pressure difference between intake air pressure (PI) and exhaust gas pressure (P2).

Fig. 4 shows a block diagram of calculation contents of EGR valve opening in a stable condition.

Fig. 5 shows a block diagram of calculation contents to determine EGR valve opening in a transient condition.

Fig. 6 shows a timing chart of change of various parameters during a transient operation.

DETAILED DESCRIPTION

[0007] Embodiments of the present disclosure are described in detail below with reference to accompanying drawings. In embodiments of the disclosure, numerous specific details are set forth in order to provide a more thorough understanding of the disclosure. However, it will be apparent to one of ordinary skill in the art that the disclosure may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid obscuring the disclosure.

[0008] In the technique disclosed in the Patent Document 1, a pressure sensor is required to be disposed to detect a pressure difference across a EGR valve, which adds an additional cost to the system.

[0009] The EGR system according to one or more embodiments of the present disclosure has an arrangement in which an EGR valve opening will be corrected and used during a transitional or transient operation depending on both an estimate of intake air pressure and an estimate of exhaust gas pressure (second estimate of exhaust gas pressure). The estimate of exhaust gas pressure has been calculated by applying a predetermined delay processing on an estimate of exhaust gas (first estimate of exhaust gas pressure) obtained based on an amount of intake air. According to one or more embodiments of the present disclosure, the transient operation may include an vehicle acceleration or deceleration where a substantial change in intake air amount takes place.

[0010] According to one or more embodiments of the present disclosure, by adjusting or correcting an opening of the EGR valve in accordance with an estimate of intake air pressure in a position in which an EGR passage is connected to an intake passage (EGR injection point) for injecting EGR gas and the second estimate of exhaust gas pressure reflecting a response delay in a position in which the EGR passage is connected to an exhaust passage (EGR extract point) for extracting or removing exhaust gas, an EGR valve opening will be controlled to maintain a substantially constant EGR rate without relying on a pressure sensor that would otherwise be necessary to measure a pressure difference across the EGR valve.

[0011] Figure 1 shows an overall configuration of the exhaust gas recirculation (EGR) system for an internal combustion engine 1 according to one or more embodiments of the present disclosure. An intake passage 2 and an exhaust passage 3 are connected to an internal combustion engine 1, respectively. Within the intake passage 2 connected to the engine 1 via an intake manifold 4 is disposed a throttle valve 5, and upstream thereof is disposed an air flow meter 6 to detect an intake air amount and an air cleaner 7. Airflow meter 6 houses a temperature sensor inside and is thus capable of detecting an intake air temperature. Within exhaust gas passage 3, which is connected to the engine 1 through an exhaust manifold 8, a catalyst 9 such as a three-way catalyst is provided for exhaust gas purification.

[0012] Moreover, internal combustion engine 1 has a turbocharger 10 with a compressor 11 disposed in intake air passage 2 and a turbine 12 coaxial with compressor 11 and disposed in exhaust gas passage 3. Compressor 11 is disposed upstream of throttle valve 5 and downstream of airflow meter 6. Turbine 12 is disposed upstream of exhaust catalyst 9. An intercooler 13 is provided downstream of throttle valve 5.

[0013] An intake air by-pass conduit 14 is connected to intake passage 2 to bifurcate therefrom, bypassing the compressor 11 and merging into intake passage 2 again. In the air by-pass conduit 14 is provided an intake air by-pass valve 15 to control an amount of by-pass air passing through air by-pass conduit 14.

[0014] An exhaust gas by-pass conduit 16 is connected to exhaust passage 3 to bifurcate therefrom, bypassing the turbine 12 and merging into exhaust passage 3 again. In the exhaust gas by-pass conduit 16 is interposed an exhaust gas by-pass valve or so-called wastegate valve 17 for controlling an exhaust gas flow within exhaust by-pass conduit 16.

[0015] In addition, the internal combustion engine 1 is configured to perform an exhaust gas recirculation (EGR) operation, and an exhaust recirculation passage (EGR passage) 20 is provided between exhaust passage 3 and intake passage 2. EGR passage 20 has one end thereof connected to exhaust gas passage 3 downstream of exhaust catalyst 9, and another end connected to intake air passage 2 at a point downstream of air cleaner 7 and upstream of compressor 11. Thus, by making use of a pressure difference between an intake air pressure and exhaust gas pressure, a part of exhaust may be recirculated and introduced into intake air passage 2 even during a supercharged operation. In the EGR passage 20 are interposed both a EGR control valve 21 and EGR cooler 22, respectively. The opening degree or openness of EGR control valve 21 is subject to a control of a control unit 25 and a desired EGR rate will be achieved depending on operative conditions of the engine. For example, at low speed, low load condition, EGR rate will be maximized, whereas, as the load and the engine speed increase, EGR rate will be controlled to decrease accordingly.

[0016] Control unit 25 receives, in addition to a detected signal of airflow meter 6, a signal from a crank angle sensor 26 to detect a crank angle of crankshaft (not shown), a signal from intake air temperature sensor 27 to detect an intake air temperature within intake manifold 4, a signal from an exhaust gas temperature sensor 28 to detect an exhaust gas temperature at an upstream side of turbine 12, a signal from an accelerator pedal opening sensor 29 to detect an depressed stroke of accelerator pedal (not shown), a signal from an atmosphere pressure sensor 30 to detect an atmospheric pressure, and the like.

[0017] Thus, in response to receipt of these signals, control unit 25 performs a control of ignition timing and air/fuel ratio of internal combustion engine 1 together with a control of exhaust gas recirculation (EGR) by adjusting opening degree of EGR control valve 21, and thereby extracting part of exhaust gas from exhaust passage 3 and recirculating into intake passage 2. The openings of throttle valve 5, intake bypass valve 15, and wastegate valve 17 are likely under control of control unit 25.

[0018] FIG. 2 shows a schematic diagram explaining an intake air pressure and exhaust gas pressure of internal combustion engine 1 according to one or more embodiments of the present disclosure. A pressure loss which is attributable to intake system including air cleaner 7 in intake passage 2 may be represented by that caused by a pseudo orifice 41 for purpose of simplicity. As an intake air amount or flow increases, the pressure differ-

ence across the pseudo orifice 41 also increases. The pseudo orifice 41 is associated with mechanical parts of intake air system and, thus, the diameter of the pseudo orifice may be considered to be constant. Thus, assuming that the intake system components upstream of EGR introduction point may be represented by the pseudo orifice 41, the intake air pressure P_1 at the EGR introduction or injection point may be calculated based on an amount of air passing through this pseudo orifice 41, and the value representing the difference pressure or a gauge pressure may increase (i.e., with a larger vacuum pressure) as the amount of intake air passing through the pseudo orifice 41 increases.

[0019] Similarly, a pressure difference due to exhaust system components such as a muffler (not shown) and a under-floor catalyst (not shown) may be regarded as another pseudo orifice 42. As in the case of above, the pressure difference $P_2 - P_0$ across the pseudo orifice 42 increases as the exhaust gas amount increases. Note that the pseudo orifice 42 is associated with mechanical parts of exhaust gas system, and thus the diameter of the pseudo orifice 42 may be considered to be constant. Thus, assuming that the exhaust system components downstream of EGR extraction point may be represented by the pseudo orifice 42, the exhaust gas pressure P_2 at this EGR extract point may be calculated based on an amount of gas passing through this pseudo orifice 42 and the value representing the difference pressure or a gauge pressure may increase as the amount of exhaust gas passing through the pseudo orifice 42 increases. The exhaust gas pressure P_2 also increases as the intake air flow increases.

[0020] Here, based on Bernoulli's Principle, the relationship between intake air amount and the square root of the difference between exhaust gas pressure P_2 and intake air pressure P_1 may be represented in FIG. 3 to show a proportional relationship therebetween. Therefore, it may be concluded that a proportional relationship is also present between intake air amount and EGR amount (i.e. EGR rate is constant). In other words, when opening of EGR valve is maintained constant, even intake air amount may change, EGR rate would not vary because of the rate of EGR amount to intake air amount is constant. It has been contemplated by the present inventor that, when an EGR gas would be injected at a point downstream of throttle valve 5, the above relationship could not be established because the pressure at EGR injection position would be significantly influenced by an opening degree of throttle valve 5 so that, even at the same intake air amount, i.e, at stable operation, an opening degree of EGR control valve 21 has to be adjusted, which might cause the entire control strategy to be more complicated. In addition, although one or more of the present embodiments includes, as an intake air charging unit, a turbocharger driven by an exhaust gas, one or more embodiments of the present disclosure may also be applicable in a system in which a supercharger is directly driven by an engine. In addition, as long as the

pressure at the EGR injection position is less than that at the EGR extract position so that an effective pressure difference for recirculation of exhaust may be generated, even the presence of the intake air charging unit as a forced induction unit may not be necessary.

[0021] FIG. 4 is a block diagram showing the contents of calculations or an arithmetic operation to obtain a valve opening of EGR control valve 21.

[0022] In S1, a target EGR rate is calculated based on a torque and engine rotation speed by referring to a target EGR rate calculation map. The torque may be calculated based on a detected value of accelerator opening sensor 29, and engine rotation speed may be obtained by a detection value of crank angle sensor 26. EGR rate calculation map may be configured by allocating target EGR rates depending on respective operation areas or regions of internal combustion engine 1.

[0023] In S2, a target EGR rate is transformed into a target opening of EGR control valve 21. In the one or more embodiments of the present disclosure, when a part of exhaust gas is recalculated from a downstream side of exhaust catalyst 9 back to upstream side of compressor 11, and EGR rate may be determinable unambiguously or directly by defining an opening degree of EGR control valve, irrespective an amount of air flow.

[0024] In S3, an estimate of exhaust gas density correction map is consulted based on an estimate of exhaust gas temperature and a exhaust gas correction coefficient will be obtained. The exhaust gas estimate is made based on an engine rotation speed detected by crank angle sensor 26 and obtainable by using a map of intake air amounts prepared with respective engine rotation speed ranges.

[0025] In S4, a reference valve opening is calculated by dividing an opening area of EGR control calculated in S2 by exhaust gas density correction coefficient obtained in S3.

[0026] In S5, the reference valve opening area will be transformed into a valve opening degree of EGR control valve 21 and an actual valve opening degree of EGR control valve 21 will be adjusted or corrected accordingly. As the reference valve area increases, the opening degree of EGR control valve 21 also increases.

[0027] During a period of transient operation, the above mentioned reference valve opening will be subjected to a transient correction (depending on valve opening area correction value) to obtain a valve opening area in the transient state, and this transitional valve opening will be transformed into an opening degree of EGR control valve 21 to control EGR control valve to match the transformed valve opening degree.

[0028] FIG. 5 is a block diagram showing the computation contents of the valve opening during a transient state. In step S11, an estimate of intake air pressure at an EGR injection point is calculated based on an intake air amount detected by airflow meter 6 and by referring to an estimate intake air pressure calculation map. The intake air pressure may be calculated on the assumption

that the pressure loss due to intake air system associated components, which are present upstream of this position, such as air cleaner 7 is represented by an orifice of constant diameter. When the intake air increases, the calculated intake air also increases in gauge.

[0029] In S12, a first estimate of exhaust gas pressure at a position of EGR extract is obtained based on the detected intake air amount of airflow meter and referring to a first exhaust gas pressure calculation map. The exhaust gas pressure at the position of EGR extract may be calculated by an intake air amount on the presumption that the pressure loss created by an exhaust gas associated component such as an underfloor catalyst (not shown) or muffler (not shown) may be represented by an orifice of constant diameter. The first estimate of exhaust gas pressure does not reflect a delay of first order and/or loss time. As the intake air increases, the calculated value for first estimate of exhaust gas pressure also increases.

[0030] In step S13, a difference between the estimated intake air pressure calculated in S11 and the first estimate of exhaust gas pressure calculated in S12 is obtained to determine a pressure difference in a stable state, *i.e.*, neglecting or ignoring the influences due to a first order delay or lag/waste time.

[0031] A delay in pressure change in response to change in intake air amount may be considered due to different location of airflow meter 6 and the location in which an actual pressure loss takes place. More specifically, when estimating an exhaust gas pressure based on intake air amount, a gas transportation delay occurs from the position of airflow meter 6 to the above mentioned EGR extract position, the timing at which the exhaust gas pressure changes at the EGR extract position will be delayed accordingly. This response delay is treated in this embodiment as a first-order time constant, loss/waste time.

[0032] In S14, based on engine rotation speed and by referring to a time constant calculation map, a time constant for delay in pressure change (a first order delay) may be calculated. As the engine rotation speed increases, the calculated time constant becomes small.

[0033] In S15, based on engine rotation speed and using a lag or waste time calculation map, a lag or waste time may be obtained. More specifically, the lag or waste time is associated with a time during which a gas or intake air is enclosed or trapped into and subsequently expelled from a combustion chamber. As the engine rotation speed increases, the calculated lag or waste time will decrease.

[0034] In S16, a second estimate of exhaust gas pressure may be calculated based upon the first estimate of exhaust gas pressure and applying the time constant obtained in S14 as well as a waste time obtained in S15 so as to the first-order time delay and waste time are taken into account.

[0035] In S17, the estimated intake air pressure and the second estimate of exhaust gas pressure calculated in S16 are used to obtain a difference so that a pressure

difference reflecting the first order delay and waste time, *i.e.*, a pressure difference in a transient state, may be obtained. Also, based on the pressure difference in the transient state and the pressure difference neglecting the first order delay and waste time, a difference or rate of these two values are obtained to calculate a valve area correction value.

[0036] In a transient state where an intake air amount varies, the EGR rate decreases when the intake air amount increases, while the EGR rate increases in response to intake air amount decreasing. When the intake air amount increases, *i.e.*, when the pressure difference between the estimated air pressure and the second estimate of exhaust gas pressure is small relative to the pressure difference between the estimated intake air pressure and the first estimate of exhaust gas pressure, an EGR rate will be reduced due to a delay in increase in the exhaust gas pressure at the EGR extract position. In contrast, when the intake air amount decreases, *i.e.*, when the pressure difference between the estimated air pressure and the second estimate of exhaust gas pressure is large relative to the pressure difference between the estimated intake air pressure and the first estimate of exhaust gas pressure, an EGR rate will be increased due to a time delay in decrease in the exhaust gas pressure at the EGR extract position.

[0037] Therefore, the valve area correction value which is calculated in S17 may be determined to take a larger value to increase an EGR gas amount as the pressure difference which reflects both a first-order delay and waste time becomes smaller as compared to the pressure difference without taking the first-order delay and waste time into account. In contrast, the valve area correction value will be smaller to decrease an EGR gas amount as the pressure difference which reflects both a first-order delay and waste time becomes larger as compared to the pressure difference ignoring the first-order delay and waste time considerations.

[0038] In S18, a transient valve area will be determined by applying a transient correction on the above mentioned reference valve area. More specifically, by multiplying the above mentioned reference valve area and the valve area correction value calculated in S17, the transient valve area will be obtained, which will be employed for adjustment of valve area to maintain the EGR rate stable during a transient operation.

[0039] FIG. 6 shows a timing chart explaining changes of various parameters over time during a transient operation.

[0040] In a transient operation of the engine where an intake amount changes, the exhaust gas pressure will change with a time delay of a timing at which an intake air amount changes. Thus, for example, when an intake air amount increases, the difference pressure between the EGR extract position and EGR injection position increases with a time delay from the change in intake air amount. Thus, as shown in FIG. 6, EGR amount will also be delayed from the change of intake air amount so that

the EGR rate will be decreased as shown in bold line in FIG. 6.

[0041] To cope with this situation and to maintain the EGR rate substantially constant irrespective of increase of intake air amount, EGR gas amount is required to increase the same change rate as that of intake air amount.

[0042] Therefore, in order to obtain a desired EGR gas amount which matches or counterbalances the increased intake air amount, prior to the increase of the difference pressure between the EGR extract position and EGR injection position, the valve area of EGR control valve 21 will be increased in advance, as indicated in dotted line in FIG. 6.

[0043] Assuming that an actual pressure difference between the EGR extract position and injection position will be detected by a pressure sensor or the like, and the opening area of EGR control valve 21 will be subsequently controlled based on the detected pressure difference, then the opening area of EGR control valve 21 may not be manipulated quickly enough. Therefore, in one or more embodiments of the present disclosure, the pressure difference between EGR extract position and EGR injection position will be estimated or predicted, and adjustment on an opening area of EGR control valve 21 will be performed, in advance.

[0044] The estimates of exhaust gas pressure at the EGR extract position may be represented either by a first estimate of exhaust gas pressure, as indicated in a dashed line in FIG. 6, which ignores or neglects the first-order delay and waste time, or by a second estimate of exhaust gas pressure, as indicated in a solid line in FIG. 6, which takes both the first-order delay and waste time into consideration. When the exhaust gas pressure at EGR extract position varies in accordance with the first estimate of exhaust gas pressure indicated in dashed line in FIG. 6, EGR rate may be kept constant even at a constant value of valve opening area of EGR control valve 21, since the EGR amount changed in a broken line in FIG. 6. However, in an actual situation, since exhaust gas pressure changes as shown in the second estimate shown in solid line in FIG. 6, lack of exhaust gas pressure will be encountered, which may be represented by a difference from the first estimate of exhaust pressure at the same timing. In order to compensate for this lack in exhaust pressure, valve area correction value will be calculated for adjustments of valve opening of EGR control valve 21 during transient periods.

[0045] As explained above, according to one or more embodiments of the present disclosure, valve opening area of EGR control valve 21 is adjusted or corrected based on an estimate of intake air pressure in a position in which EGR passage is connected to intake passage 2 and a second estimate of exhaust gas pressure which is determined by taking a response delay into account in a position in which the EGR passage is connected to exhaust passage (EGR extract position). Therefore, even in a transient state of operation, EGR rate will be controlled with a sufficient accuracy, *i.e.*, kept constant.

[0046] Moreover, since the pressures both at the EGR injection position and EGR extract position are estimated based on an intake air amount, the valve opening of EGR control valve 21 may be controlled to maintain a constant EGR rate without relying on use of a sensor to actually detect pressures prior to and after EGR valve 21.

[0047] According to one or more embodiments of the present disclosure, an influence of exhaust gas temperature on exhaust gas pressure is considered, and the valve opening area is further corrected depending on the exhaust gas temperature.

[0048] While the disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised.

[0049]

- | | |
|----|----------------------------|
| 1 | Internal combustion engine |
| 2 | Intake passage |
| 3 | Exhaust passage |
| 5 | Throttle valve |
| 6 | Airflow meter |
| 9 | Exhaust catalyst |
| 10 | Turbocharger |
| 11 | Compressor |
| 12 | Turbine |
| 13 | Intercooler |
| 20 | EGR passage |
| 21 | EGR control valve |
| 22 | Control unit |

Claims

1. An exhaust gas recirculation device for an internal combustion engine (1) having an intake air charging unit, comprising:

an intake air passage (2) that intakes intake air for the internal combustion engine (1);
 an exhaust passage (3) that carries away exhaust gas from the internal combustion engine (1);
 an exhaust gas recirculation passage (20) connected to the intake air passage (2);
 an exhaust gas recirculation valve (21) interposed within the exhaust gas recirculation passage (20); and
 an intake air charging unit comprising:

a compressor (11) disposed in the intake air passage (2);
 a turbine (12) disposed in the exhaust passage (3);

wherein the exhaust gas recirculation passage (20) recirculates a part of the exhaust gas based on an openness of the exhaust gas recirculation

valve (21) to control an amount of exhaust re-circulation introduced into the intake air passage (2),
 wherein a first end of the exhaust gas recirculation passage (20) is connected to the intake air passage (2) upstream of the compressor (11) of the intake air charging unit,
 wherein a second end of the exhaust gas recirculation passage (20) is connected to the exhaust passage (3) downstream of the turbine (12) of the intake air charging unit,
 wherein the exhaust gas recirculation device further comprises:

an intake air detecting means for detecting an amount of the intake air upstream of the compressor (11);

an intake air pressure estimating means for estimating an intake air pressure in a position in which the first end of the exhaust recirculation passage (20) is connected based on the detected amount of the intake air;

a first exhaust gas pressure calculating means for calculating a first estimate of exhaust gas pressure in a position in which the second end of exhaust gas recirculation passage (20) is connected based on the detected amount of the intake air; and

a second exhaust gas pressure calculating means for calculating a second estimate of exhaust gas pressure by applying a predetermined response-delay processing on the first estimate of exhaust gas pressure, and

wherein the opening of the exhaust gas recirculation valve (21) is adjusted based on a second pressure difference between the estimated intake air pressure and the second estimate of the exhaust gas pressure.

2. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1, wherein

the intake air detecting means is an intake air detecting unit;

the intake air pressure estimating means is an intake air pressure estimate unit;

the first exhaust gas pressure calculating means is a first exhaust gas pressure calculating unit; and

the second exhaust gas pressure calculating means is a second exhaust gas pressure calculating unit.

3. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1 or claim 2,

wherein the exhaust gas recirculation valve (21) is further adjusted based on a first pressure difference between the estimated intake air pressure and the first estimate of the exhaust gas pressure.

4. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 3, wherein, when the first pressure difference is smaller than the second pressure difference, the openness of the exhaust gas recirculation valve (21) is adjusted to increase an amount of recirculation gas, and wherein, when the first pressure difference is larger than the second pressure difference, the openness of the exhaust gas recirculation valve (21) is adjusted to decrease the amount of recirculation gas.

5. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1 or claim 2, wherein the predetermined delayed processing is made based on a time constant defined based on an engine speed and a lag time.

6. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 3, wherein the predetermined delayed processing is made based on a time constant defined based on an engine speed and a lag time.

7. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 4, wherein the predetermined delayed processing is made based on a time constant defined based on an engine speed and a lag time.

8. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1 or claim 2, further comprising:

a throttle valve (5) disposed in the intake air passage to control an amount of air introduced into the internal combustion engine (1), wherein the first end of the exhaust gas recirculation passage (20) is positioned upstream of the throttle valve (5).

9. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1 or claim 2, further comprising:

a control means for determining a transient operation of the internal combustion engine (1), and adjusting the opening of the exhaust gas recirculation valve (21) upon determination of the engine transient operation.

10. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 9 when dependent on claim 2, wherein the control means is

a controller (25).

11. The exhaust gas recirculation device for an internal combustion engine (1) according to claim 1, wherein:

the intake air detecting means comprises an air-flow meter (6) that detects an air flow upstream of the position where the exhaust gas recirculation passage (20) is injected into the intake air passage (2); and
the intake air pressure estimating means, the first exhaust gas pressure calculating means and the second exhaust gas pressure calculating means form part of a control unit (25) configured to further perform
the adjustment of the opening of the exhaust gas recirculation control valve (21).

Patentansprüche

1. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) mit einer Ansaugluftladeeinheit, umfassend:

einen Ansaugluftdurchlass (2) zur Zufuhr von Ansaugluft für den Verbrennungsmotor (1);
einen Abgasdurchlass (3) zur Abfuhr von Abgas von dem Verbrennungsmotor (11);
einen mit dem Ansaugluftdurchlass (2) verbundenen Abgasrückführdurchlass (20);
ein innerhalb des Abgasrückführdurchlasses angeordnetes Abgasrückführventil (21); und
eine Ansaugluftladeeinheit, umfassend:

einen in dem Ansaugluftdurchlass (2) angeordneten Kompressor (11);
eine in dem Abgasdurchlass (3) angeordnete Turbine (12);
wobei in dem Abgasrückführdurchlass (20) ein Teil des Abgases in Abhängigkeit von dem Öffnungsgrad des Abgasrückführventils (21) zurückgeführt wird, das dazu ausgebildet ist, eine in den Ansaugluftdurchlass (2) eingeführte Abgasmenge zu steuern,
wobei ein erstes Ende des Abgasrückführdurchlasses (20) vor dem Kompressor (11) der Ansaugluftladeeinheit mit dem Ansaugluftdurchlass (2) verbunden ist,
wobei ein zweites Ende des Abgasrückführdurchlasses (20) hinter der Turbine (12) der Ansaugluftladeeinheit mit dem Abgasdurchlass (3) verbunden ist,
wobei die Abgasrückführvorrichtung des Weiteren umfasst:

ein Ansaugluftefassungsmittel zur Erfassung einer Ansaugluftmenge vor dem Kompressor (11);

ein Ansaugluftdruckschätzmittel zur Schätzung eines Ansaugluftdrucks an einer Position, an der das erste Ende des Abgasrückführdurchlasses (20) verbunden ist, auf der Basis der erfassten Ansaugluftmenge;
ein erstes Abgasdruckberechnungsmittel zur Berechnung einer ersten Schätzung des Abgasdrucks an einer Position, an der das zweite Ende des Abgasrückführdurchlasses (20) verbunden ist, auf der Basis der erfassten Ansaugluftmenge; und
ein zweites Abgasdruckberechnungsmittel zur Berechnung einer zweiten Schätzung des Abgasdrucks durch Anwendung einer vorbestimmten Ansprechverzögerungsverarbeitung der ersten Schätzung des Abgasdrucks, und
wobei der Öffnungsgrad des Abgasrückführventils (21) auf der Basis einer zweiten Druckdifferenz zwischen dem geschätzten Ansaugluftdruck und der zweiten Schätzung des Abgasdrucks eingestellt wird.

2. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1, wobei
das Ansaugluftefassungsmittel eine Ansaugluftefassungseinheit ist;
das Ansaugluftdruckschätzmittel eine Ansaugluftdruckschätzungseinheit ist;
das erste Abgasdruckberechnungsmittel eine erste Abgasdruckberechnungseinheit ist; und
das zweite Abgasdruckberechnungsmittel eine zweite Abgasdruckberechnungseinheit ist.

3. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1 oder Anspruch 2, wobei
das Abgasrückführventil (21) des Weiteren auf der Basis einer ersten Druckdifferenz zwischen dem geschätzten Ansaugluftdruck und der ersten Schätzung des Abgasdrucks eingestellt wird.

4. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 3, wobei, wenn die erste Druckdifferenz geringer ist als die zweite Druckdifferenz, der Öffnungsgrad des Abgasrückführventils (21) derart eingestellt wird, dass eine Rückführgasmenge erhöht wird, und
wobei, wenn die erste Druckdifferenz höher ist als die zweite Druckdifferenz, der Öffnungsgrad des Abgasrückführventils (21) derart eingestellt wird, dass eine Rückführgasmenge verringert wird.

5. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1 oder Anspruch 2, wobei die vorbestimmte Verzögerungsverarbeitung auf der Basis einer Zeitkonstanten durchgeführt wird, die auf der Basis einer Motordrehzahl und einer Verzögerungszeit definiert ist. 5
6. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 3, wobei die vorbestimmte Verzögerungsverarbeitung auf der Basis einer Zeitkonstanten durchgeführt wird, die auf der Basis einer Motordrehzahl und einer Verzögerungszeit definiert ist. 10
7. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 4, wobei die vorbestimmte Verzögerungsverarbeitung auf der Basis einer Zeitkonstanten durchgeführt wird, die auf der Basis einer Motordrehzahl und einer Verzögerungszeit definiert ist. 15
20
8. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1 oder Anspruch 2, die des Weiteren umfasst: 25

ein in dem Ansaugluftdurchlass angeordnetes Drosselventil (5) zur Steuerung einer in den Verbrennungsmotor (1) zugeführten Luftmenge, wobei das erste Ende des Abgasrückfuhrdurchlasses (20) vor dem Drosselventil (5) angeordnet ist. 30
9. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1 und Anspruch 2, die des Weiteren umfasst: 35

ein Steuerungsmittel zur Erfassung eines Übergangsbetriebs des Verbrennungsmotors (1) und zum Öffnungsgrad des Abgasrückfuhrventils (21) bei Erfassung des Übergangsbetriebs des Verbrennungsmotors. 40
10. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 9, soweit abhängig von Anspruch 2, wobei das Steuerungsmittel eine Steuerung (25) ist. 45
11. Abgasrückführvorrichtung für einen Verbrennungsmotor (1) gemäß Anspruch 1, wobei das Ansaugluftefassungsmittel eine Luftmengenmesseinrichtung (6) umfasst, die eine Luftmenge vor der Position, an der der Abgasrückfuhrdurchlass (20) in den Ansaugluftdurchlass (2) führt, erfasst; und 50

das Ansaugluftdruckschätzmittel, das erste Abgasdruckberechnungsmittel und das zweite Abgasdruckberechnungsmittel Teil einer Steuereinheit (25) bilden, die des Weiteren dazu ausgebildet ist, die Einstellung des Öffnungsgrads des Abgasrück-

fuhrsteuerungsventils (21) durchzuführen.

Revendications

1. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) ayant une unité de charge d'air d'admission, comprenant :

un passage d'air d'admission (2) qui admet l'air d'admission pour le moteur à combustion interne (1) ;
un passage d'échappement (3) qui évacue les gaz d'échappement du moteur à combustion interne (1) ;
un passage de recirculation des gaz d'échappement (20) relié au passage d'air d'admission (2) ;
une valve de recirculation des gaz d'échappement (21) interposée dans le passage de recirculation des gaz d'échappement (20) ; et
une unité de charge d'air d'admission comprenant :

un compresseur (11) disposé dans le passage d'air d'admission (2) ;
une turbine (12) disposée dans le passage d'échappement (3) ;

dans lequel le passage de recirculation des gaz d'échappement (20) fait recirculer une partie des gaz d'échappement sur la base d'une ouverture de la valve de recirculation des gaz d'échappement (21) pour commander une quantité de recirculation d'échappement introduite dans le passage d'air d'admission (2),
dans lequel une première extrémité du passage de recirculation des gaz d'échappement (20) est reliée au passage d'air d'admission (2) en amont du compresseur (11) de l'unité de charge d'air d'admission,
dans lequel une seconde extrémité du passage de recirculation des gaz d'échappement (20) est reliée au passage d'échappement (3) en aval de la turbine (12) de l'unité de charge d'air d'admission,
dans lequel le dispositif de recirculation des gaz d'échappement comprend en outre :

un moyen de détection d'air d'admission pour détecter une quantité d'air d'admission en amont du compresseur (11) ;
un moyen d'estimation de pression d'air d'admission pour estimer une pression d'air d'admission dans une position dans laquelle la première extrémité du passage de recirculation d'échappement (20) est reliée, sur la base de la quantité détectée d'air

- d'admission ;
un premier moyen de calcul de pression des gaz d'échappement pour calculer une première estimation de la pression des gaz d'échappement dans une position dans laquelle la seconde extrémité du passage de recirculation des gaz d'échappement (20) est reliée, sur la base de la quantité détectée d'air d'admission ; et
un second moyen de calcul de pression des gaz d'échappement pour calculer une seconde estimation de pression des gaz d'échappement en appliquant un traitement à retard de réponse prédéterminé à la première estimation de pression des gaz d'échappement, et
- dans lequel l'ouverture de la valve de recirculation des gaz d'échappement (21) est réglée sur la base d'une seconde différence de pression entre la pression d'air d'admission estimée et la seconde estimation de la pression des gaz d'échappement.
2. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1, dans lequel
le moyen de détection d'air d'admission est une unité de détection d'air d'admission ;
le moyen d'estimation de la pression d'air d'admission est une unité d'estimation de la pression d'air d'admission ;
le premier moyen de calcul de la pression de gaz d'échappement est une première unité de calcul de la pression de gaz d'échappement ; et
le second moyen de calcul de pression des gaz d'échappement est une seconde unité de calcul de la pression des gaz d'échappement.
 3. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1 ou 2,
dans lequel la valve de recirculation des gaz d'échappement (21) est en outre réglée sur la base d'une première différence de pression entre la pression d'air d'admission estimée et la première estimation de la pression des gaz d'échappement.
 4. Dispositif de recirculation de gaz d'échappement pour moteur à combustion interne (1) selon la revendication 3,
dans lequel, lorsque la première différence de pression est inférieure à la seconde différence de pression, l'ouverture de la valve de recirculation de gaz d'échappement (21) est réglée pour augmenter une quantité des gaz de recirculation, et
dans lequel, lorsque la première différence de pression est supérieure à la seconde différence de pression, l'ouverture de la valve de recirculation des gaz d'échappement (21) est réglée pour diminuer la quantité des gaz de recirculation.
 5. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1 ou 2,
dans lequel le traitement retardé prédéterminé est effectué sur la base d'une constante de temps définie sur la base d'une vitesse moteur et d'un temps de retard.
 6. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 3,
dans lequel le traitement retardé prédéterminé est effectué sur la base d'une constante de temps définie sur la base d'une vitesse moteur et d'un temps de retard.
 7. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 4,
dans lequel le traitement retardé prédéterminé est effectué sur la base d'une constante de temps définie sur la base d'une vitesse moteur et d'un temps de retard.
 8. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1 ou 2, comprenant en outre :
un papillon des gaz (5) disposé dans le passage d'air d'admission pour commander une quantité d'air introduite dans le moteur à combustion interne (1),
dans lequel la première extrémité du passage de recirculation des gaz d'échappement (20) est positionnée en amont du papillon des gaz (5).
 9. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1 ou 2, comprenant en outre :
un moyen de contrôle pour déterminer un fonctionnement transitoire du moteur à combustion interne (1), et régler l'ouverture de la valve de recirculation des gaz d'échappement (21) après détermination du fonctionnement transitoire du moteur.
 10. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 9 lorsqu'elle est dépendante de la revendication 2, dans lequel le moyen de contrôle est un régulateur (25).
 11. Dispositif de recirculation des gaz d'échappement pour moteur à combustion interne (1) selon la revendication 1, dans lequel :

le moyen de détection d'air d'admission comprend un débitmètre d'air (6) qui détecte un flux d'air en amont de la position où le passage de recirculation des gaz d'échappement (20) est injecté dans le passage d'air d'admission (2) ; et 5
le moyen d'estimation de pression d'air d'admission, le premier moyen de calcul de pression des gaz d'échappement et le second moyen de calcul de pression des gaz d'échappement font 10
partie d'une unité de commande (25) configurée pour effectuer, en outre,
le réglage de l'ouverture de la valve de recirculation de gaz d'échappement (21).

15

20

25

30

35

40

45

50

55

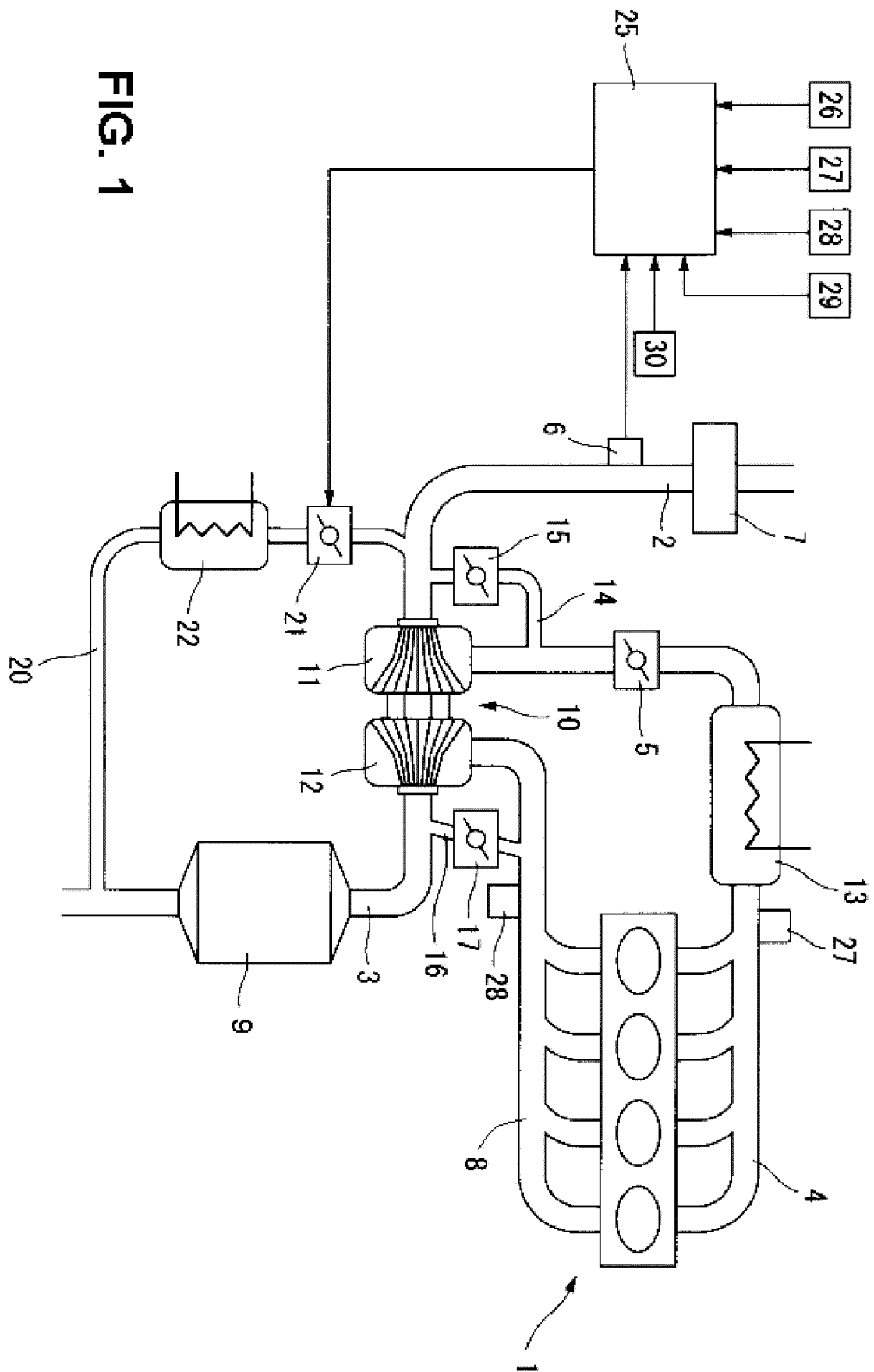


FIG. 1

FIG. 2

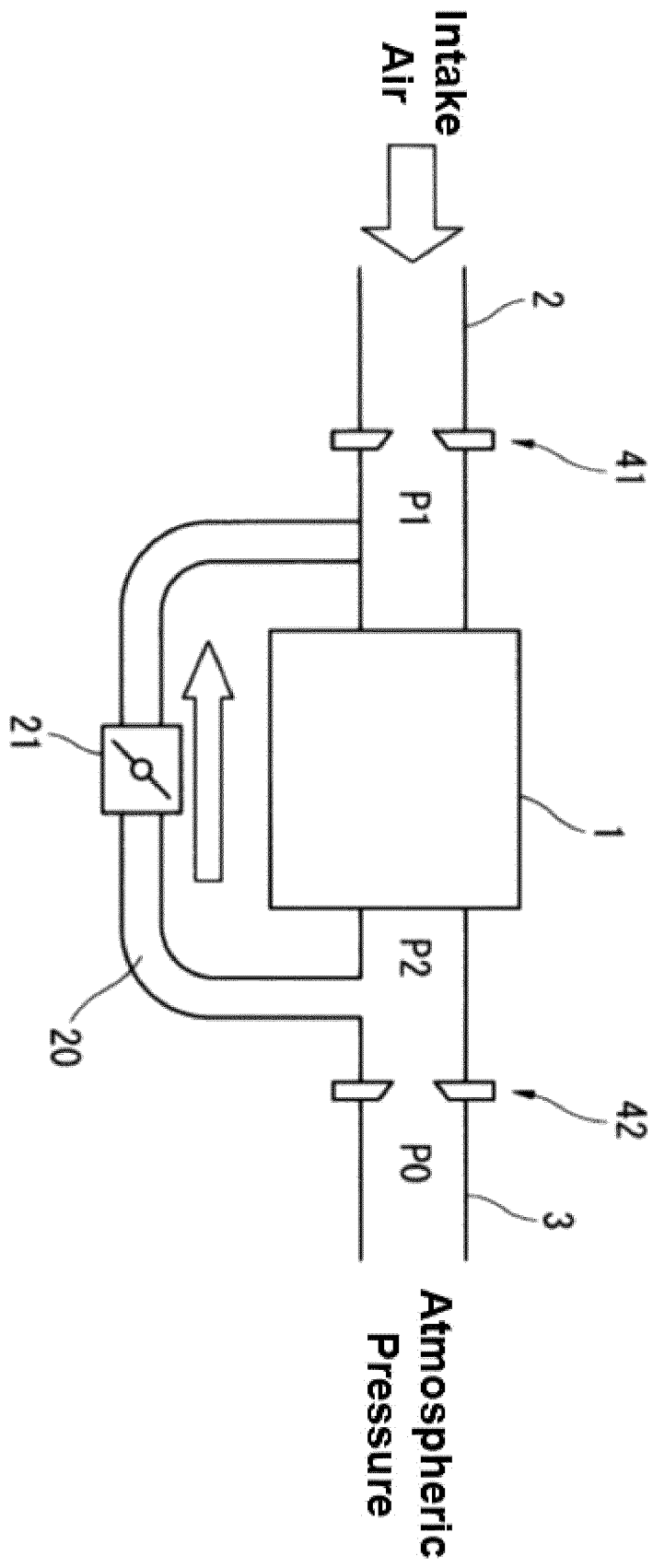


FIG. 3

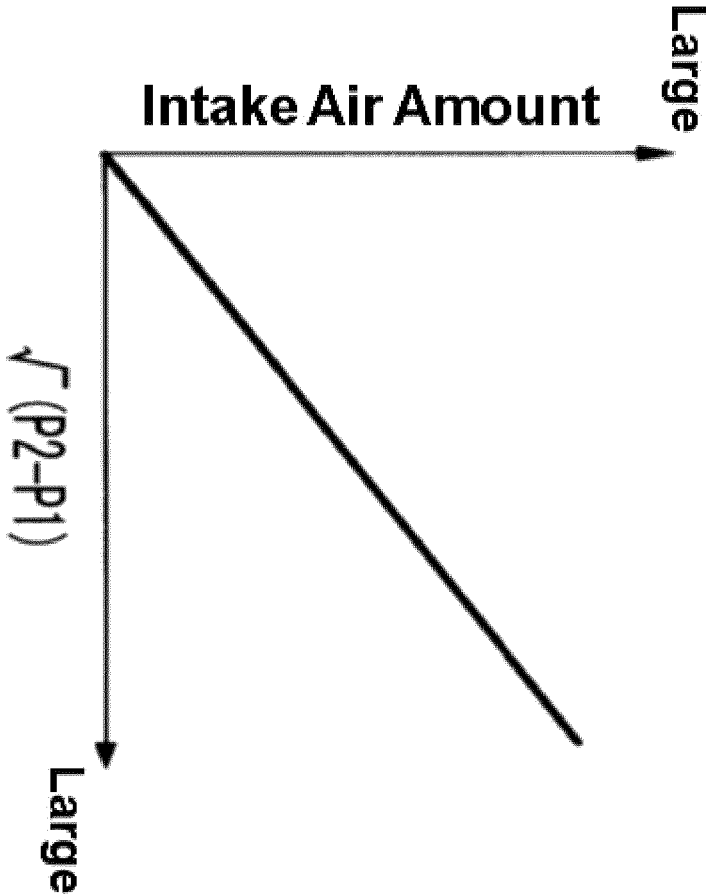


FIG. 4

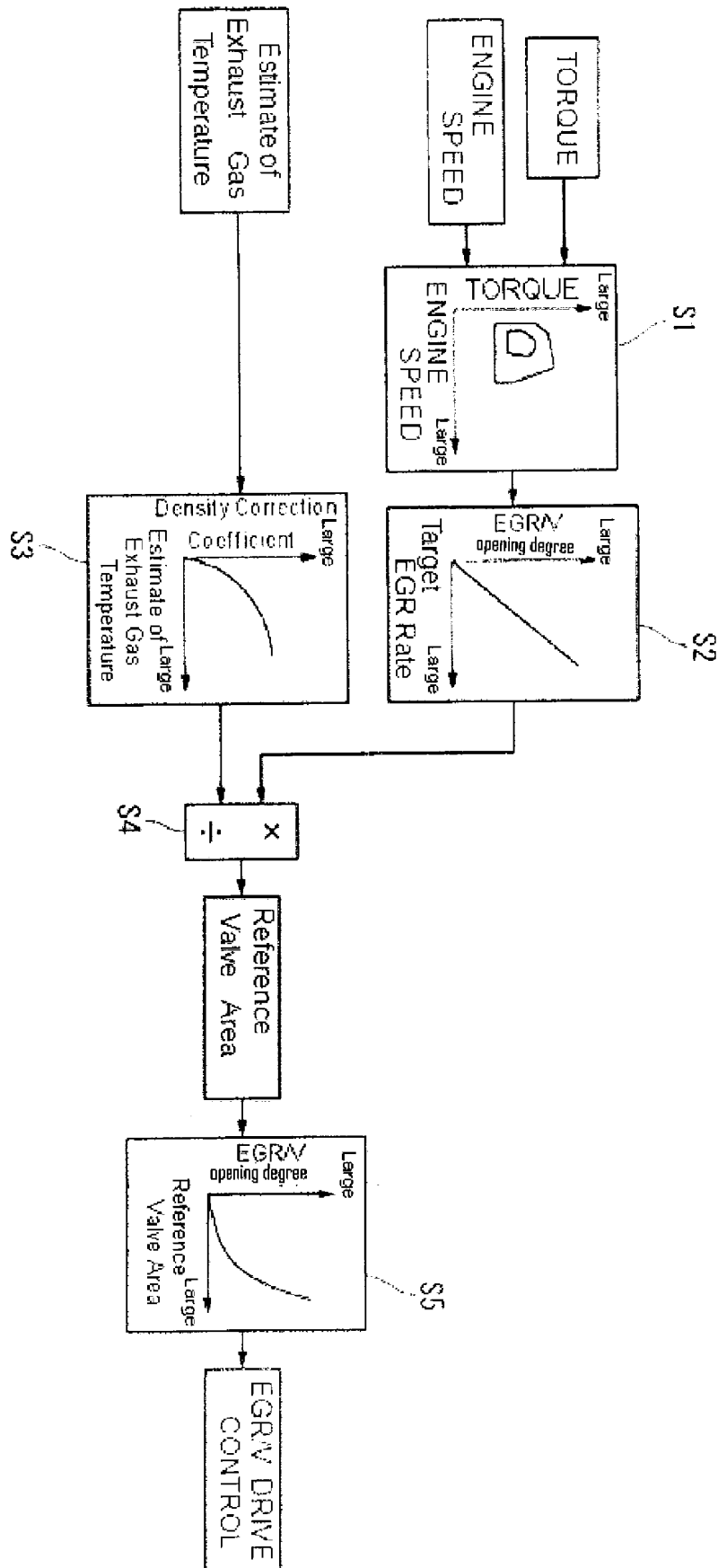


FIG. 5

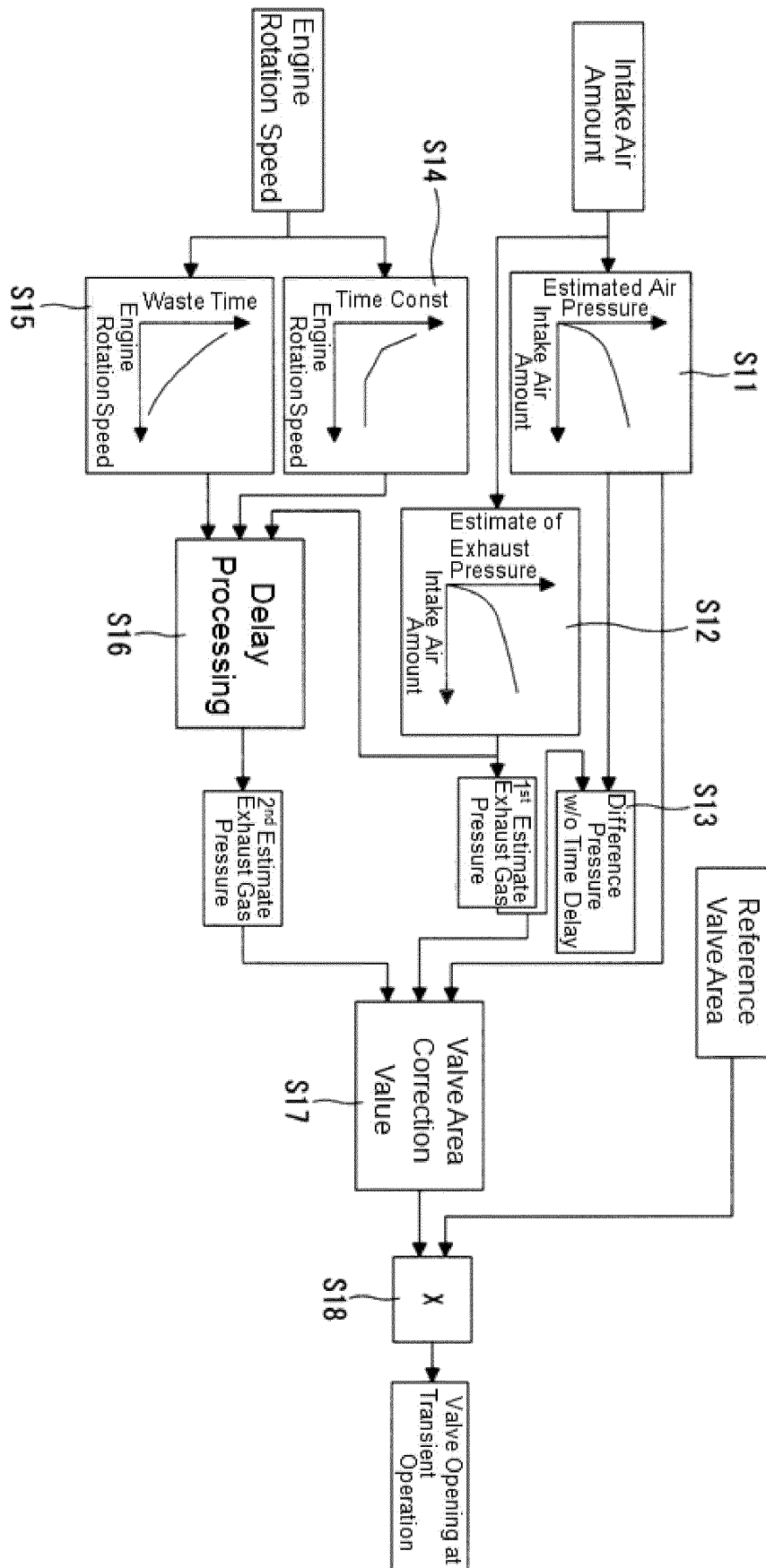
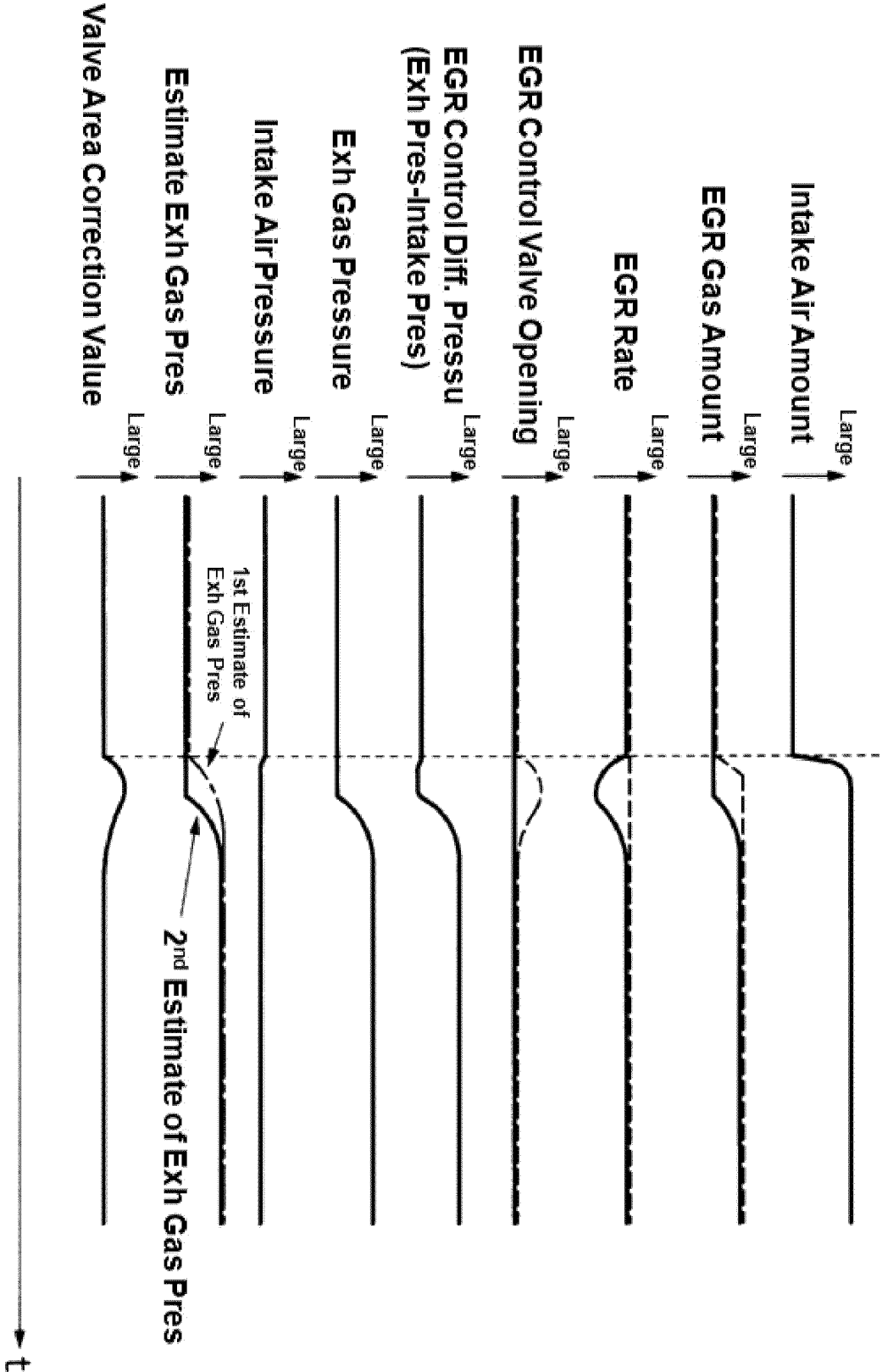


FIG. 6



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004150343 A [0003]
- US 6868329 B, Ito [0003]
- US 2003004677 A1 [0003]
- EP 2447516 A1 [0003]
- US 6732522 B2 [0003]